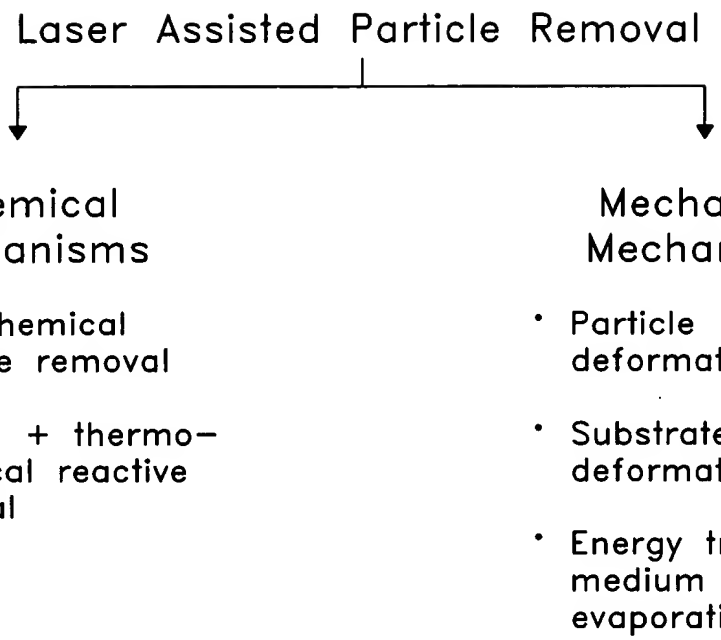
Laser Assisted Particle Removal
Chemical Mechanisms
• Photochemical reactive removal
• Photo– + thermo– chemical reactive removal
Mechanical Mechanisms
• Particle deformation
• Substrate deformation
• Energy transfer medium explosive evaporation

FIG. 1

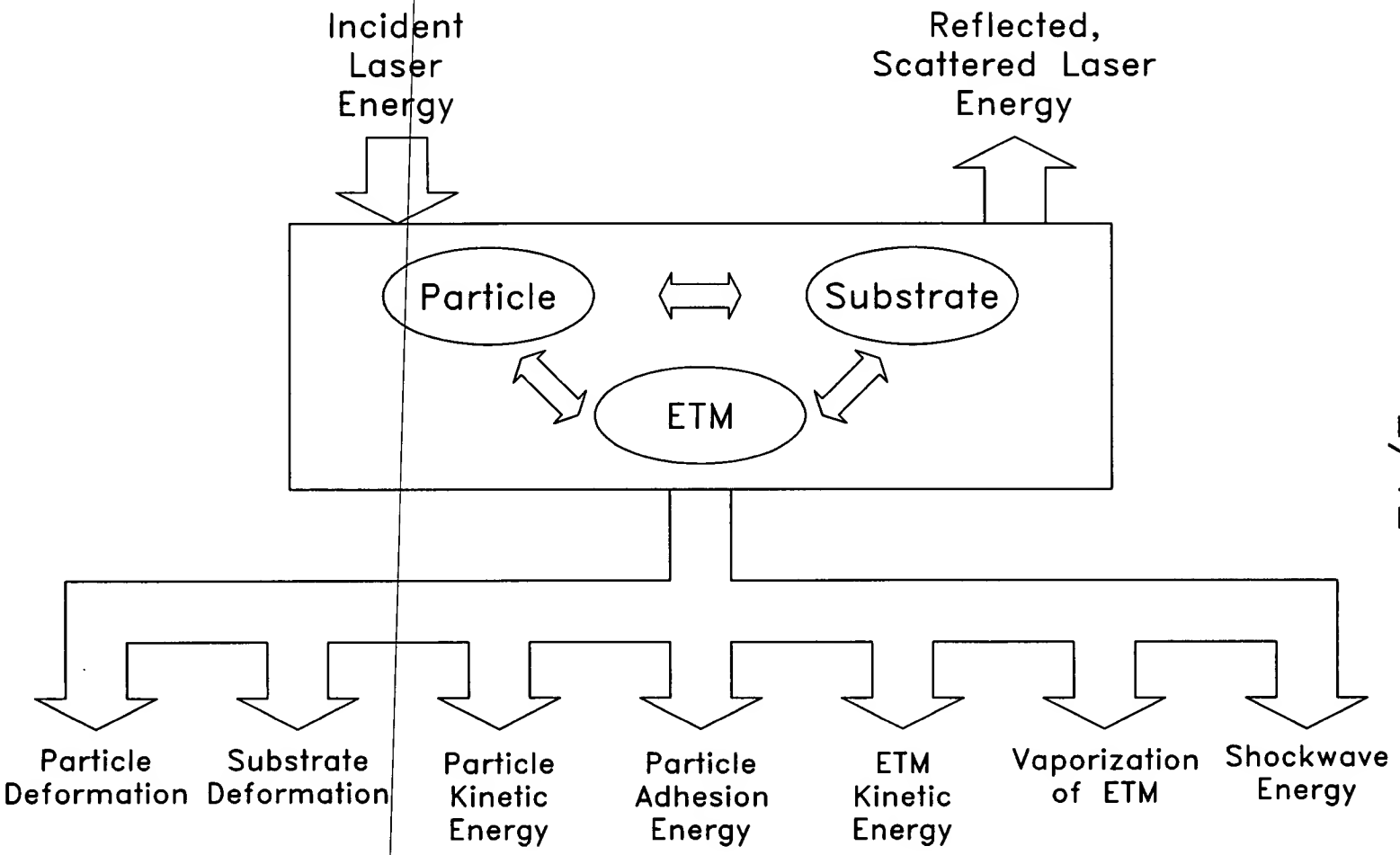
Incident Laser Energy
Reflected, Scattered Laser Energy
Particle
Substrate
ETM
Particle Deformation
Substrate Deformation
Particle Kinetic Energy
Particle Adhesion Energy
ETM Kinetic Energy
Vaporization of ETM
Shockwave Energy

FIG. 2

Absorption Medium	Particle	ETM	Substrate with ETM	Substrate without ETM
Removal Mechanism	Rapid thermal expansion of particle	Explosive evaporation of ETM	Microbubble formation at liquid/solid interface	Rapid thermal expansion of the substrate
wavelength	λ<<Particle Diameter	λ>>Particle Diameter	λ>Particle Diameter	λ>>Particle Diameter or λ<Particle Diameter if $\alpha_{particle}$ is low
Energy Absorption	$\alpha_{particle} >> \alpha_{substrate}$	High α_{ETM}	High $\alpha_{substrate}$	High $\alpha_{substrate}$
Substrate Damage	-Melting/Ablation of particle	Shockwave, substrate absorption	-Melting/Ablation of particle or substrate -Shockwave in ETM	Melting/Ablation of particle or substrate
Particle Removal Threshold	Φ_{th}=0.01-0.08 J/cm^2 I_{th} =1-11 MW/cm^2 D=20μm	Φ_{th}=0.65-2.2 J/cm^2 I_{th} =3-11 MW/cm^2	Φ_{th}=0.02-0.3 J/cm^2 I_{th} =2-600 MW/cm^2 t=0.03-20 ns	Φ_{th}=0.02-0.3 J/cm^2 I_{th} =1-30 MW/cm^2 t=7-30 ns

FIG. 3

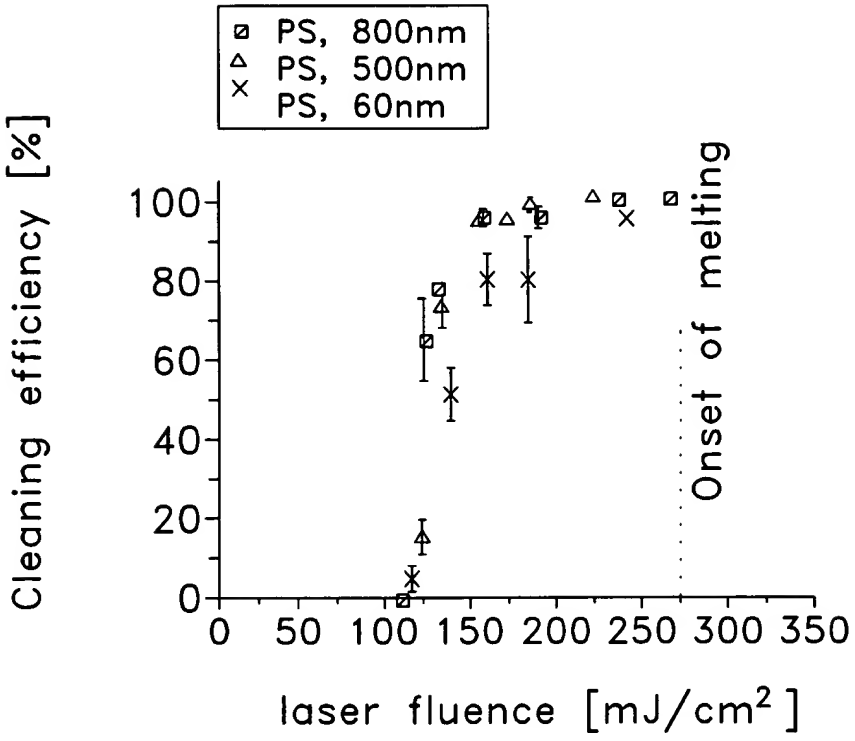
PS, 800nm
PS, 500nm
PS, 60nm
Cleaning efficiency [%]
100
80
60
40
20
0
0
50
100
150
200
250
300
350
Onset of melting
laser fluence [mJ/cm²]

FIG. 4

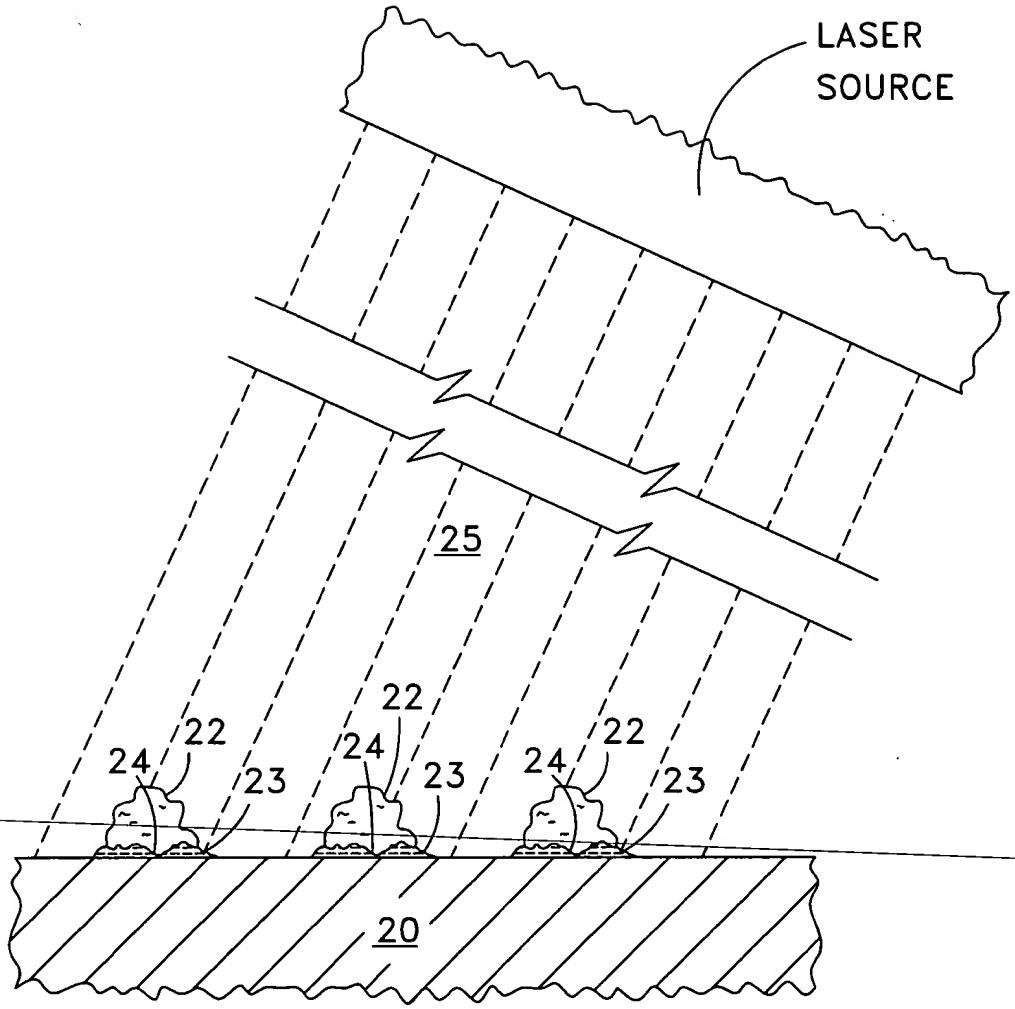

FIG. 5

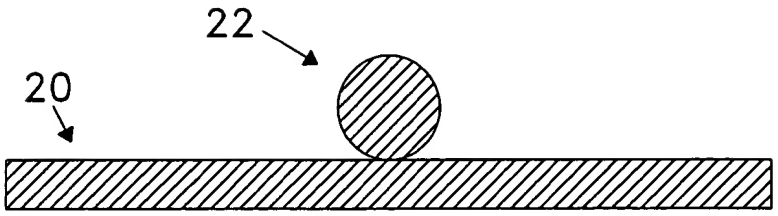

FIG. 6A

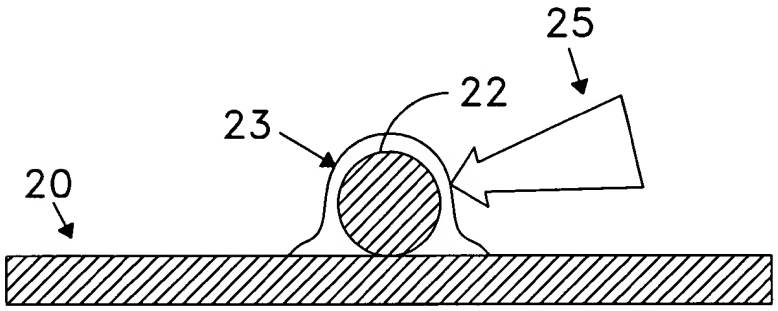

FIG. 6B

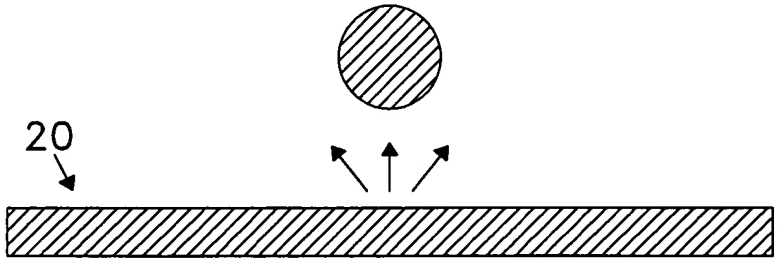

FIG. 6C

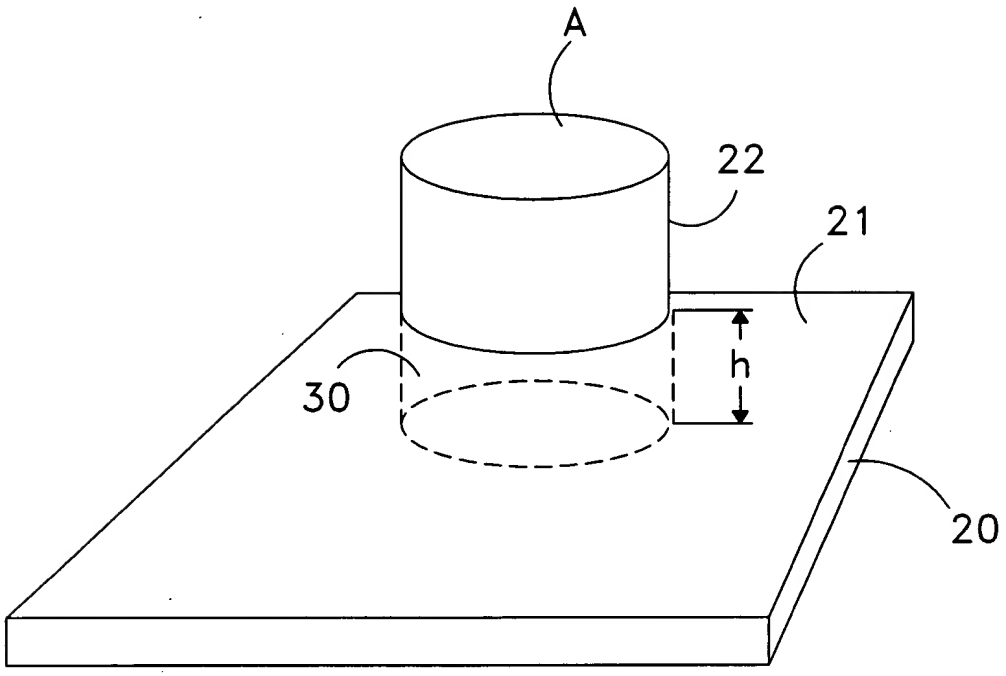

FIG. 7

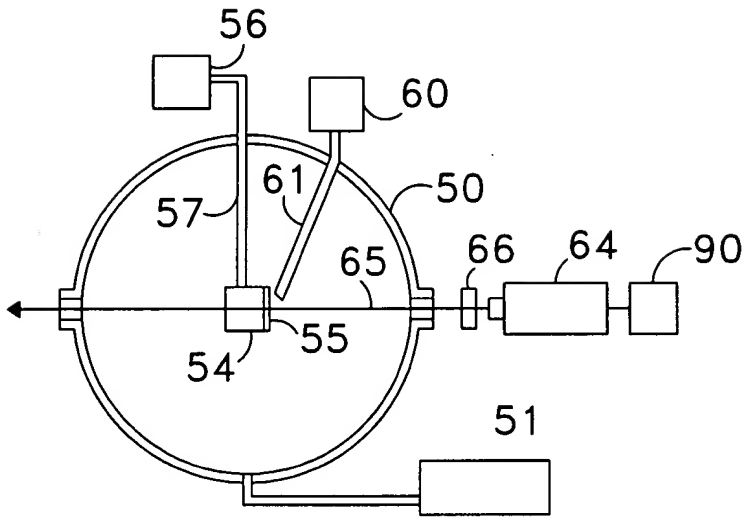

FIG. 8

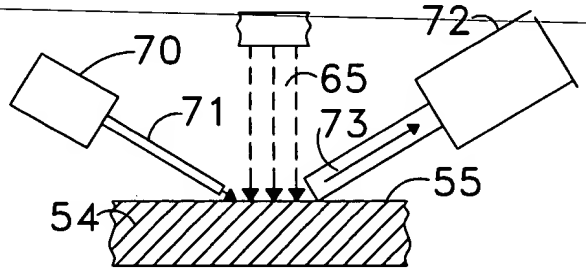

FIG. 9

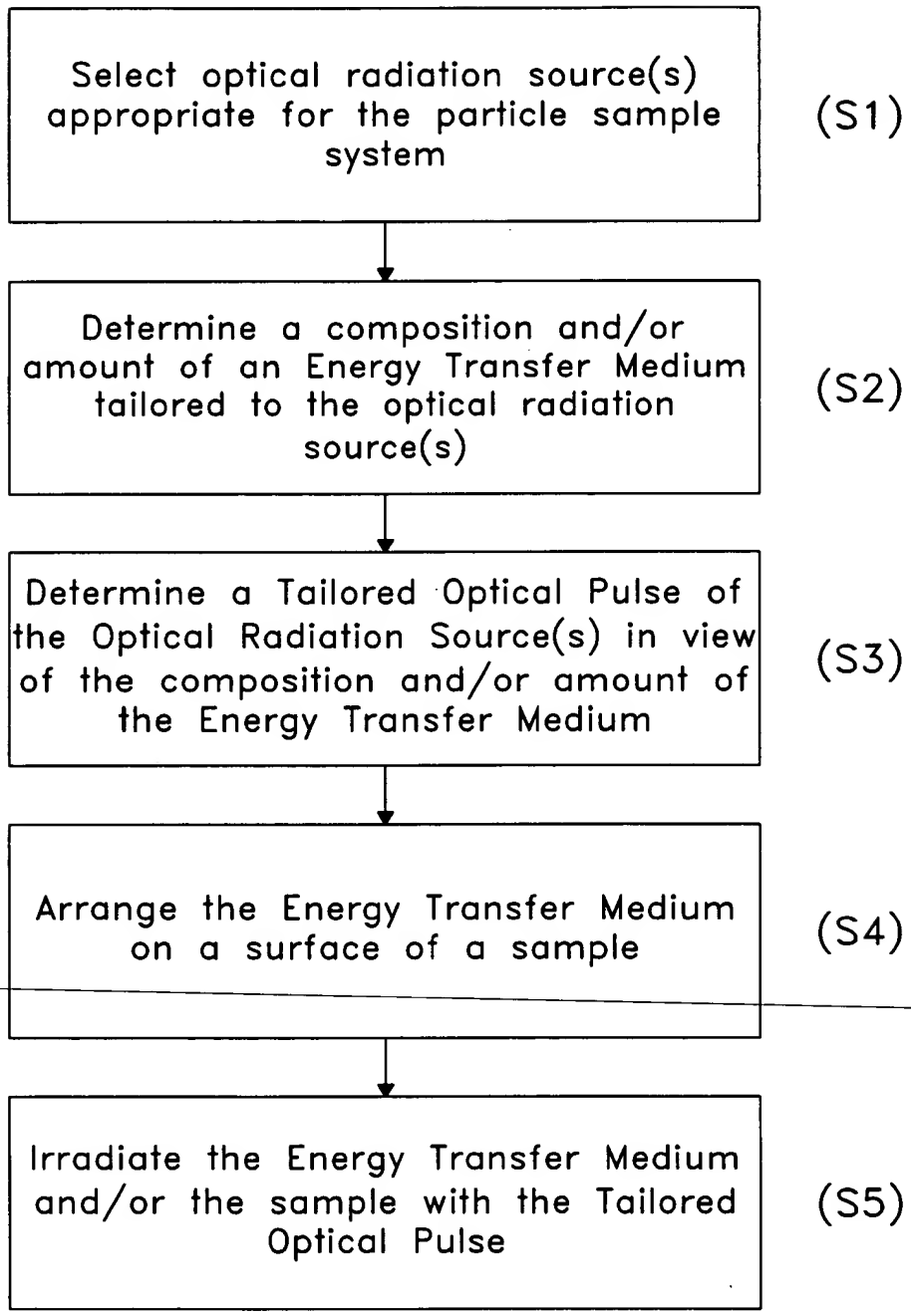
Select optical radiation source(s) appropriate for the particle sample system
(S1)
Determine a composition and/or amount of an Energy Transfer Medium tailored to the optical radiation source(s)
(S2)
Determine a Tailored Optical Pulse of the Optical Radiation Source(s) in view of the composition and/or amount of the Energy Transfer Medium
(S3)
Arrange the Energy Transfer Medium on a surface of a sample
(S4)
Irradiate the Energy Transfer Medium and/or the sample with the Tailored Optical Pulse
(S5)

FIG. 10

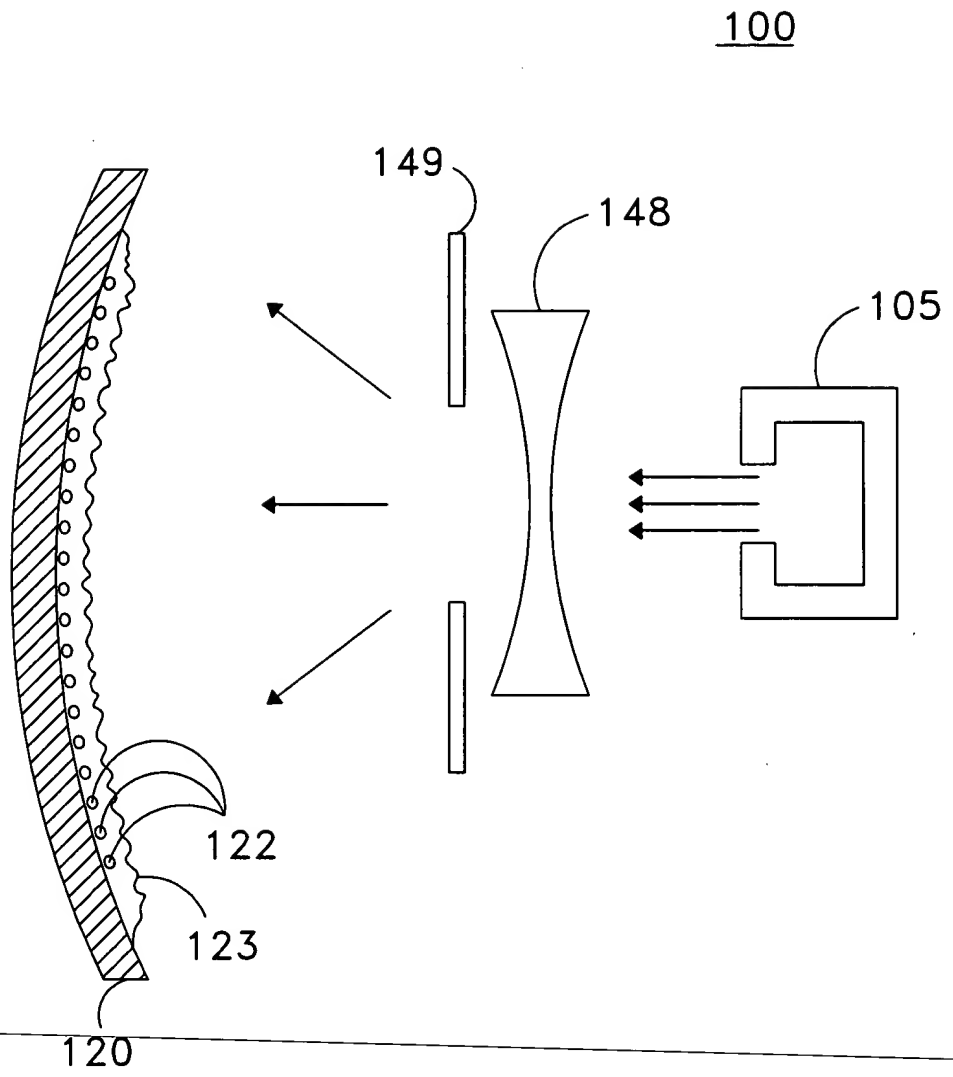

FIG. 11

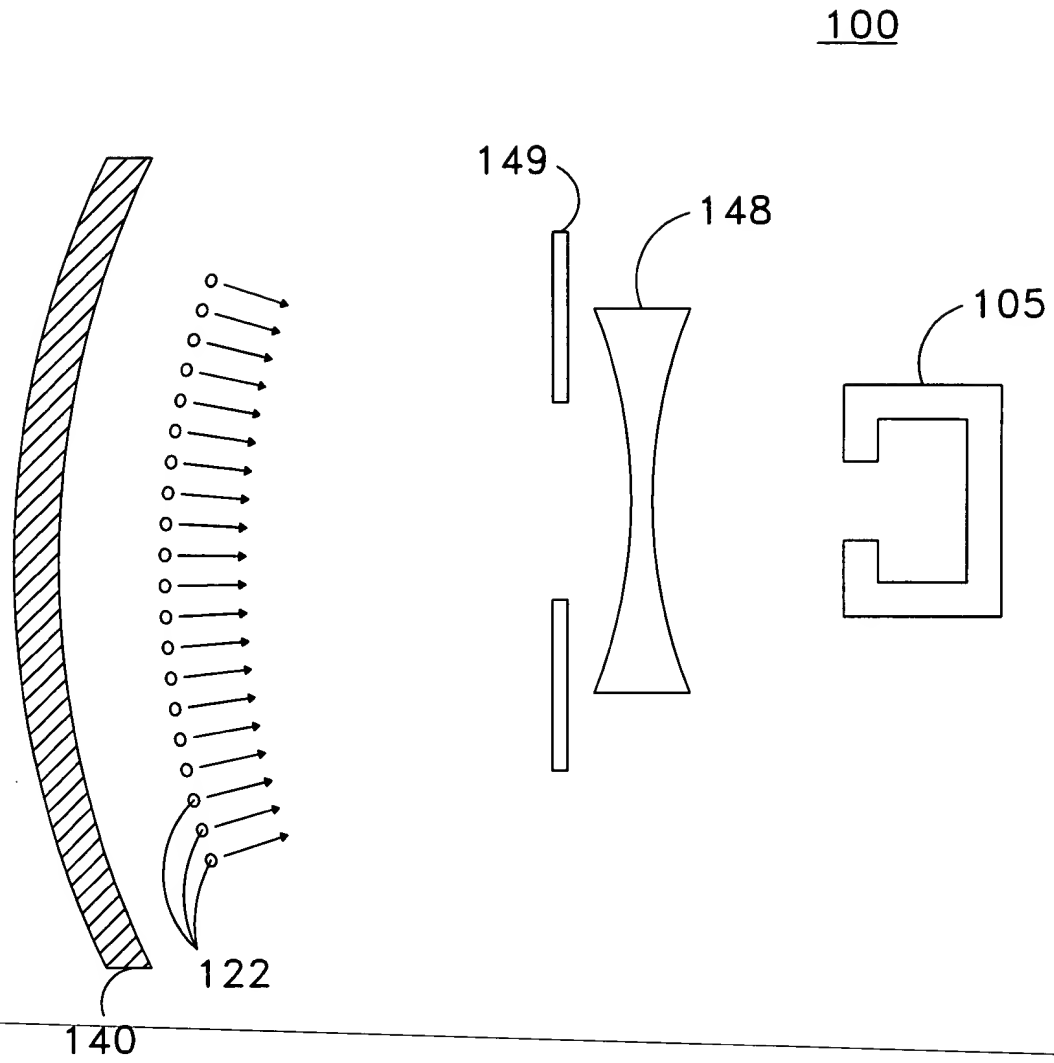

FIG. 12

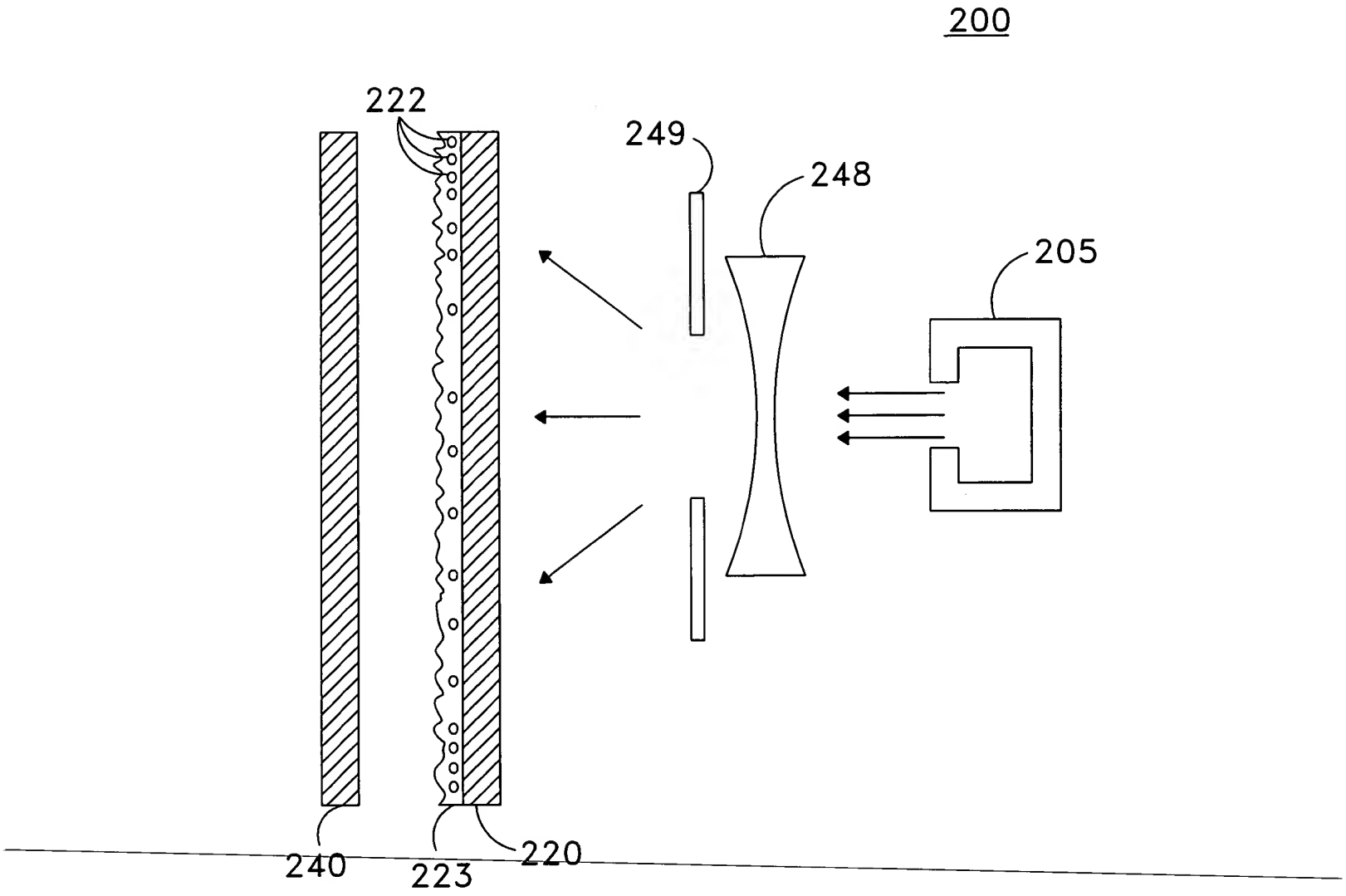

FIG. 13